Research and Development at the Detector Systems Branch

NASA Goddard Space Flight Center

Laddawan R. Miko
Branch Head

Our Mission

To provide sensors/detectors and devices and help enable scientists to:

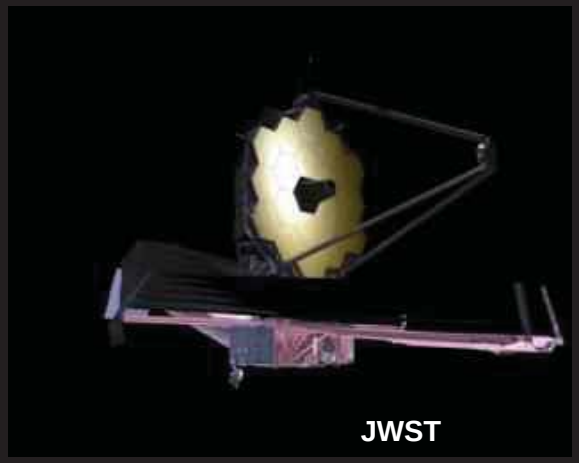
- Conduct experimental research to explore the solar system and understand the formation and evolution of planetary systems
- Conduct experimental research in astronomy and astrophysics to help answer compelling scientific questions:
  - *How alone are we?*
  - *What is the ultimate destiny of the Universe?*
  - *What are the large-scale population properties and distributions of the objects we can see in the sky?*
- Conduct experimental research on our planet's natural systems and processes including climate change, the atmosphere, the oceans, and the land surface.

Our Experience

- The Detector Systems Branch specializes in design, fabrication and testing of detectors and MEMS/Nano devices for ground based, airborne and space flight.
- Beginning with the Hubble Space Telescope, the Branch has successfully developed and characterized detector systems for many high-profile missions and instruments.
- We put this experience to work in our continued support of NASA and international space agencies.


SPITZER
SDO
Cassini
Hubble
WFC 3
New Horizons
Landsat 8
ACS
Astro E
SWIFT/BAT
EO-1
Completed Missions

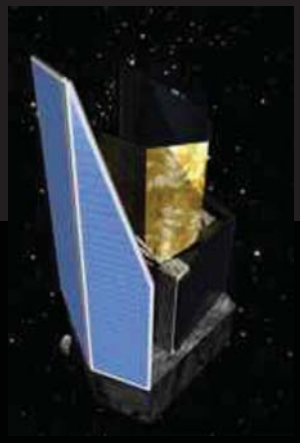
Astro H



JWST

WFIRS
T

OSIRIS-REX



Euclid

Future Missions

Detector Systems Branch Facilities

Development/ Fabrication

- Detector Development Laboratory (DDL)
- Detector Packaging Laboratory

Testing/ Characterization

- Detector Characterization Laboratory (DCL)
- Cryogenic Detector Test Facility
- MEMS/Nano test facility

The Detector Development Laboratory (DDL)

- The DDL is a microelectronics fabrication facility dedicated to the development of advanced detectors, micro-electrical-mechanical-systems (MEMS), nanotechnology, circuits, and components for NASA's missions.
- The laboratory is built around a 4,800 square foot, class 10/100 clean room housing an extensive array of semiconductor processing equipment to perform full-scale custom wafer fabrication.

Wet Chemistry Benches for Acids, Bases, and Solvents

- The laboratory contains a large variety of semiconductor fabrication equipment for optical and electron beam lithography, wet and dry etching, oxidation, diffusion, thin film deposition, metallization, ion implantation, thin film metrology, and device characterization.

DDL Current mission

- JWST /Microshutter development
- PIXIE
- HAWC+
- ATHENA
- MicroSpec
- CLASS

Current Development on cryogenic detectors

- **Transition Edge Sensor (TES)** detectors are being or will be used on
  - **CLASS: Cosmology Large Angular Scale Surveyor** telescope at

    40GHz, 90GHz, 150GHz, 220GHz, operate at 0.15K for cosmic

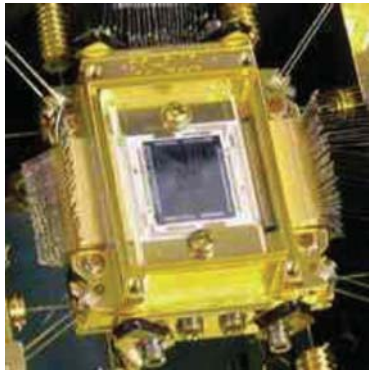
    microwave background polarization (CMBPol)
  - **PIPER: Primordial Inflation Polarization Explorer**: Frequency 200-600GHz, operate at 0.1K
  - **HAWC+: High-resolution Airborne Wideband Camera:** Spectral range 40um to 300um, 40x60 array, Galactic and Extragalactic dust emission and star formation
  - **GISMO: Goddard-IRAM Superconducting 2mm Observer:** Wavelength 2mm, 8x16 array, Science application Galactic and Extragalactic dust emission

Current Development on cryogenic detectors

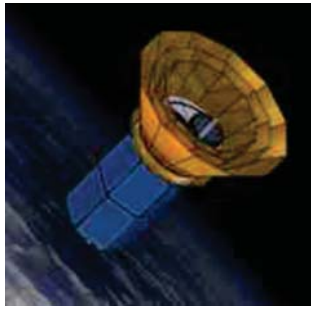
- **Magnetic Calorimeters**
  - Metallic Magnetic Calorimeters (MMCs)
  - Magnetic Penetration Thermometers (MPTs)
- **Kinetic Inductance Detectors** (KID)

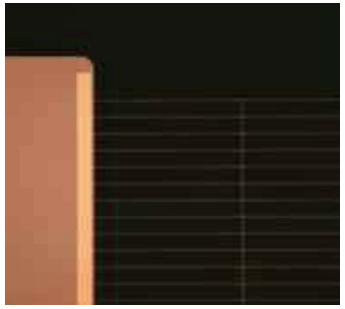
  Microspec, STARFIRE and QUBIC
- **Micro calorimeter**
  - **ASTRO-H** high-resolution X-ray calorimeter spectrometer (Soft X-ray Spectrometer [SXS]) (0.3-10Kev, 50mK)
  - PIXIE for FIR

Cryogenic Detectors

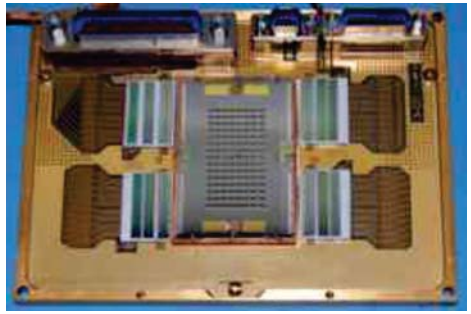


Astro-H (flight)

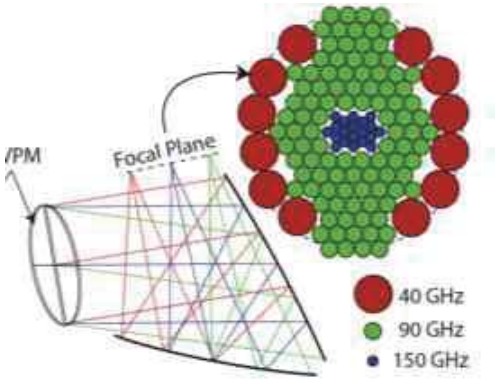




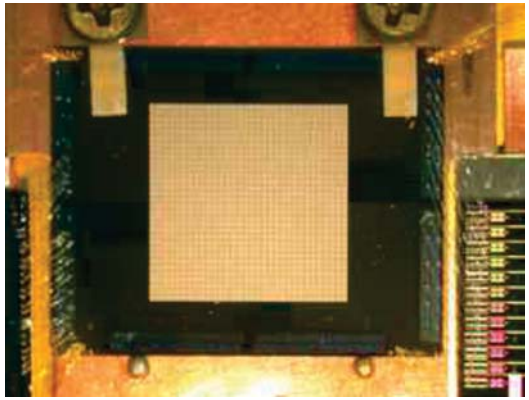
Primordial Inflation Explorer (PIXIE)



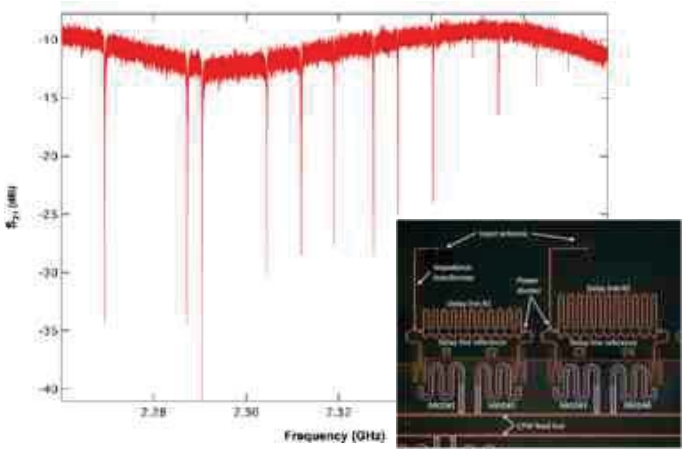
Primordial Inflation Polarization Explorer (PIPER)



Cosmology Large Angular Scale Surveyor (CLASS)



TES Detector Arrays for ATHENA (International X-ray Observatory)



Microwave Kinetic Inductance Detector array for μ-Spec/SOFIA and future misions

Cryogenic Detector Testing Lab

- ^{3}He refrigerator for cryogenic microwave measurement. Base temperature of ~ 235 mK.

- The dilution refrigerator has a base temperature of 7 mK, a cooling power of 560 microwatts at 100 mK, a 170 mm diameter sample space at the cold end.

^{3}He refrigerator

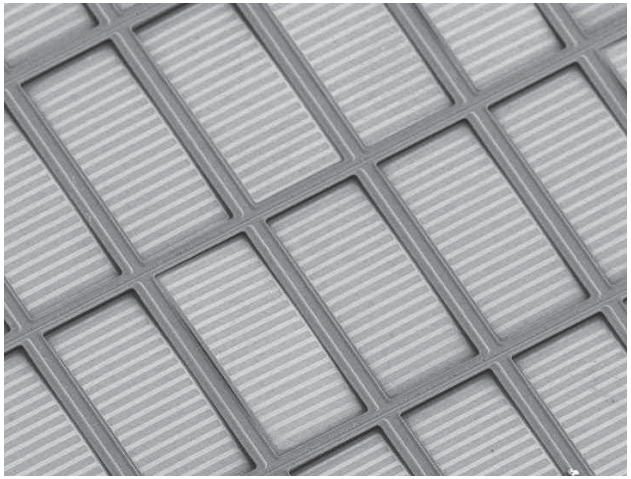
Dilution refrigerator

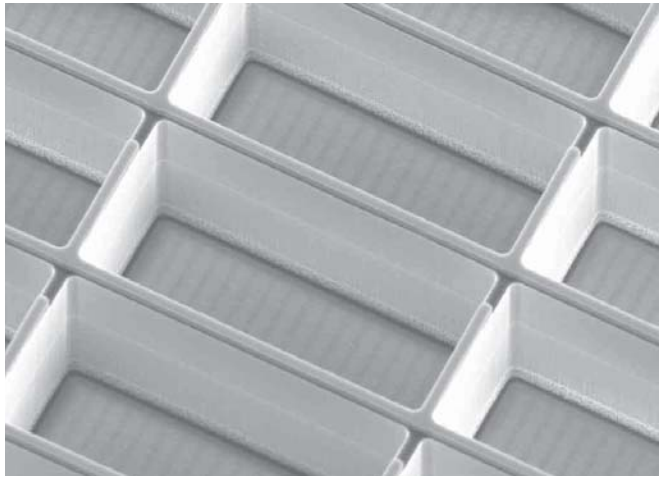
Current MEMS/NANO research

- Graphene-based chemical sensor

Low pressure CVD for graphene growth

- Next-generation Microshutters

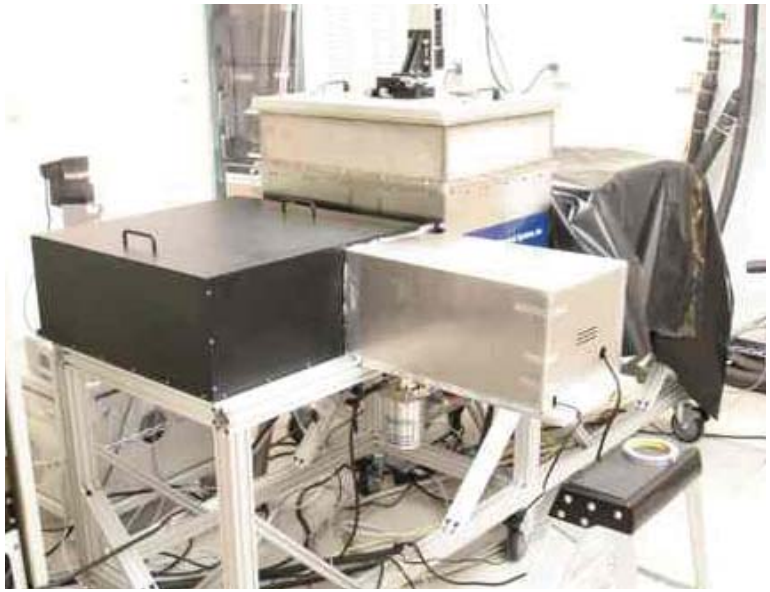




SEM micrographs of Microshutter Array

MEMS Testing Lab

- MEMS and nanotechnology testing facility supports flight JWST microshutter array life cryo-testing.
- Class 1000 clean tent facility
- Characterize MEMS devices for failure analysis and contrast ratios.



Life Test & Contrast Dewar

Microshutter Quadrant

Detector Characterization Lab

Detector Systems Branch (Code 553)
Instrument Systems & Technology Division
NASA Goddard Space Flight Center

DCL – Our Mission

The DCL supports every aspect of the definition, procurement, and verification of state-of-the-art flight detector systems operating from ultraviolet through infrared. We provide advanced independent detector verification and characterization critical for mission success.

Detector Characterization Labs (DCL)

- DCL is a world-class facility for complete optical and electrical characterization of custom detectors -from individual detectors to large format focal plane arrays operating from the UV and Visible to the far IR spectrum
- ASIC test system has been developed for IR and CCD detectors. ASIC based CCD electronics developed at DCL has been used for ACS Repair mission. ASIC based readout electronics is used for NirSpec FPA testing.
- Data analysis: All test data are archived and analyzed on the DCL server system

Facility Details

Full infrastructure for detector characterization:

- Class 100 and 1000 clean room areas for testing contamination-sensitive detectors and detector subsystems - ensure state of the art characterization of custom research-grade and flight detectors
- Test cryostats for single detectors and up to 800 mm diameter focal plane arrays.
- Broad range of test electronics – laboratory-grade “gold standards” to highly-integrated ASICs – to support differing requirements.
- Data analysis and archiving on the DCL servers provide collaborative access and data retention.

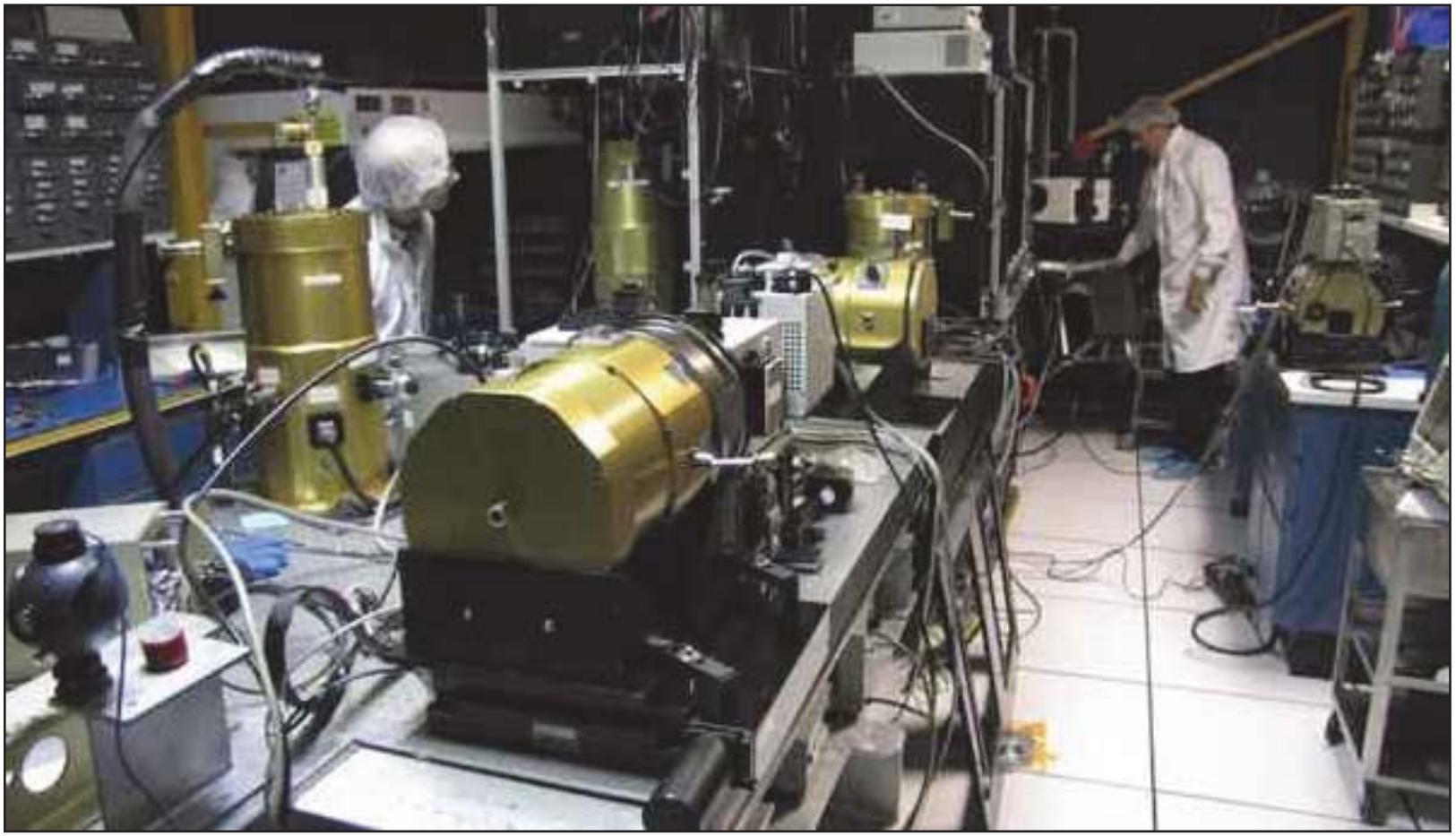
DCL Current missions

- Euclid
- WFIRST
- JWST/NIRSpec
- OSIRIS-REX/OVIRS
- ORCA
- CLARREO
- VIIRS

Flight Detectors Tested by DCL

- ACS/CCDs for Hubble
- InSb detetcors on IRAC/Spitzer
- CIRS instrument on Cassini
- WFC3/H1R for Hubble
- LEISA/Picnic Array on New Horizon mission to Pluto
- TIRS/QWIP, Landsat8
- JMAPS/H4RG
- NIRSpec/H2RG , JWST
- Euclid/H2RG
- WFIRST/H4RG

HST Lab

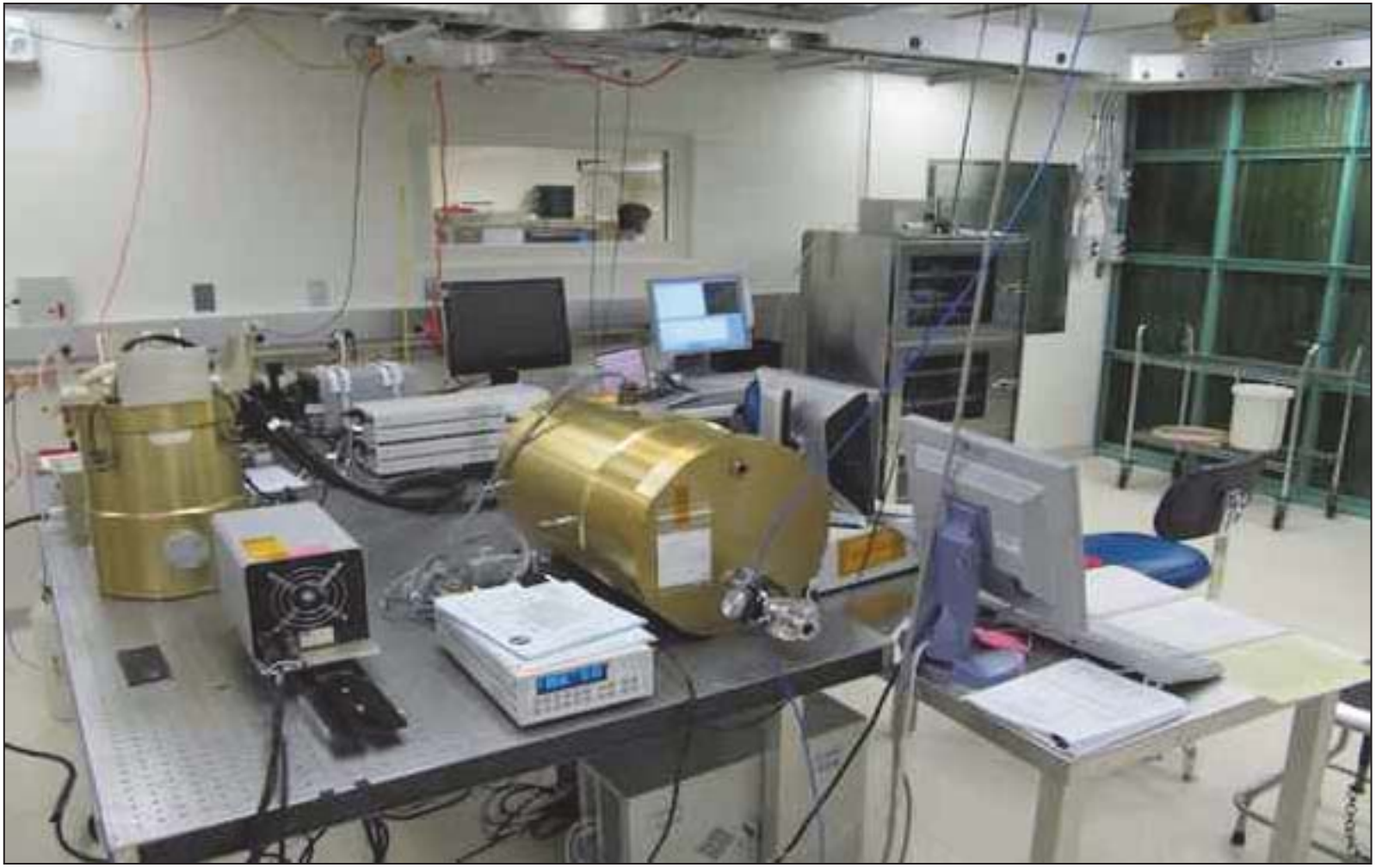


Established in 1998, the HST Lab is still in use in Building 20 at GSFC.

DCL – WFIRST/Euclid Lab

WFIRST/Euclid Lab – Established 2011

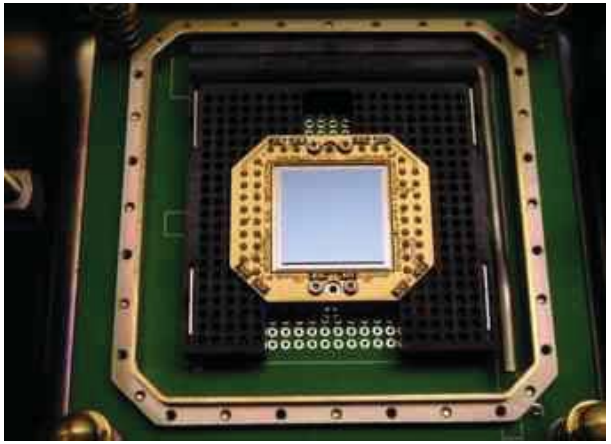
TIRS Lab for LDCM



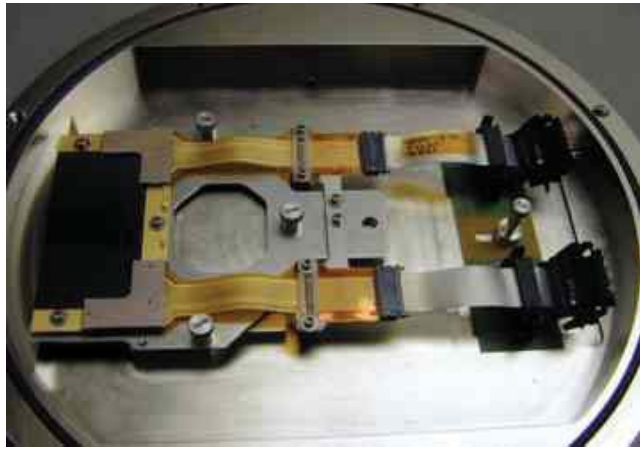
The TIRS Lab for the LCDM in Building 11 at GSFC, circa mid 2000s.

NIRSpec Lab for JWST

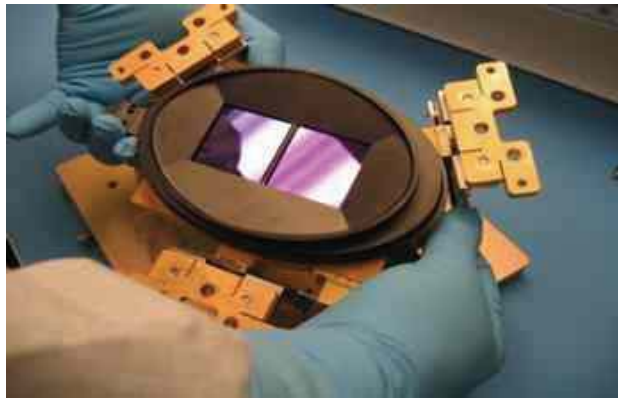
Flight Detectors Tested by DCL



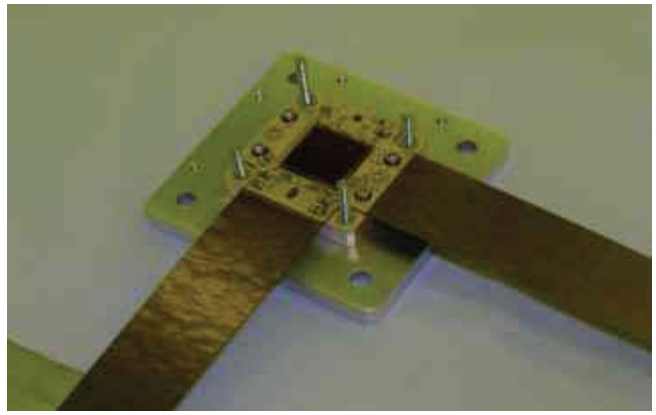
WFC3 infrared H1R HgCdTe 1kx1k



WFC3 CCD



JWST NIRSpec DS ETU
(Two HAWAII-2RG SCAs)



New Horizons: Linear Etalon Imaging Spectral Array (LEISA)

Flight Detectors Tested by DCL

NIRSpec testing Facility

JMAPS test Dewar

Flight Detectors Tested by DCL

Cryo Electronics testing Dewar

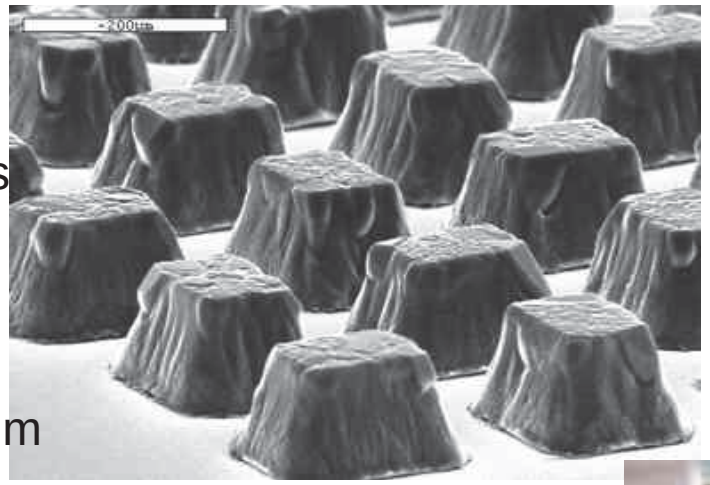
WFIRST test Dewar

DCL-Applicable Experience

- The DCL has extensive experience with the components that will comprise the NASA contribution to the Euclid detector system:
  - HST WFC3 – developed the first 1.7 μm cutoff HgCdTe near-IR detectors (Rockwell).
  - JWST H2RG and SIDECAR ASIC – 2K x 2K IR detectors that are now the “standard” and highly integrated electronics (Teledyne).
  - HST ACS-R – used the SIDECAR ASIC to control CCDs – first flight of the SIDECAR.
  - SIDECAR ASIC Improvements – based on experience with HST ACS-R and NIRSpec (Teledyne).
  - WFIRST H4RG – increase pixel count and density to support large format focal plane arrays in volume-constrained instruments (Teledyne).
  - WFIRST – contact resistance experiments to decrease noise and improve yield (Teledyne).
  - LDCM/TIRS - used the SIDECAR ASIC to control QWIP detector

Packaging Capabilities:
Indium Hybridization

- Room temperature indium bump bonding is used for bonding two or more die together for various applications such as cryogenic MEMS devices, small pixel pitch detectors, heat-sensitive materials, and low-outgassing applications.
- The two die are carefully cleaned using solvents, single-hair brushes, and gas plasma processing. Then, the FC150 is used to align and compress the indium bumps of the two die together. Because the indium bumps will stick together at room temperature, no heating (a.k.a. reflowing) is required.
- The resulting bond of the two die (now called a hybrid) is strong enough that many applications do not require additional mechanical support.
- Other applications may require epoxy underfilling the resulting hybrid to reinforce the bond.



Indium Bumps

Indium Deposition

MEMS Lab – FC150 Flip Chip Bonder

For More Information

We routinely follow a project from the initial concept through the design, construction, and characterization phases all the way to the final implementation of the project.

Our people have the expertise to make this possible, with extensive experience in a broad array of disciplines including detector physics, micro-fabrication, detector characterization, and engineering of high-performance detector systems.

For more information about the Detector Systems Branch at Goddard Space Flight Center, visit:

http://detectors.gsfc.nasa.gov